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Cytogeography of the *Aster ageratoides* Complex (Asteraceae) in Korea

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This is the first report on chromosome number of the *Aster ageratoides* complex in Korea, which is one of the representatives of Sino-Japanese elements. Our cytogeographical research reveals that both diploids and tetraploids occur in Korea. Diploids are dominant and widely distributed through Korea including Cheju Island, while tetraploids are limited to the southeastern part of the Korean Peninsula. The leaf shape of diploids shows a clinal variation from lanceolate to ovate toward south. At the south end of this peninsula, lanceolate leaved diploids and ovate leaved diploids are sometimes sympatric in several populations. Tetraploids also have a leaf shape variation from lanceolate to ovate even within a population. The plants with elliptic-lanceolate or lanceolate leaves are identified as *A. ageratoides* var. *ageratoides*. Although a taxonomical treatment still waits for further consideration, the resemblance between the ovate leaved plants in Korea and *A. ageratoides* var. *ovalifolius*, known as endemic to Japan, is noted.

Key words: *Aster ageratoides*, Asteraceae, cytogeography, Korea, polyploidy

The *Aster ageratoides* complex, comprised of polyploid series, is one of the Sino-Japanese elements distributed widely from southwestern China, Korea, Taiwan to Japan, and has many intra-specific taxa and closely related species (Kitamura 1993, Soejima & Peng 1998a). In the *A. ageratoides* complex, one species and ten varieties in China (Ling & Chen 1985), one species and one variety in Taiwan (Soejima & Peng 1998b), and five species and three varieties in Japan (Ito & Soejima 1995) were recorded. But in Korea, *A. ageratoides* var. *ageratoides* with elliptic-lanceolate leaves has only been recorded, and there is no record of its chromosome number.

In this study, we made field observation and counted the chromosome numbers for the plants collected from about 60 populations in Korea. The results are described in relation to the geographical distribution and their morphological features.

Materials and methods

More than 250 plants were collected from 62 populations in Korea (Table 1, Fig. 1). Among them, chromosome numbers were counted for a total of 189 plants collected from 51 populations. For cytological observation, root tips obtained from the potted plants were used. Root tips were stored in iced water for about 24 hours, and fixed with ethanol and acetic acid (3:1). Maceration and staining were

TABLE 1. Sampling localities and chromosome numbers determined

Locality		2n[a]	Pop.No.[b]
Seoul-si	Bukhan-san, Dobong-gu	18 (4)	3
Gyoeng-gi-do	Gwangneung, Sohol-myeon, Pocheon-gun	18 (3)	4
	Heungryong-sa, Idong-myeon, Gapyeong-gun	18 (1)	5
	Gwangdeog, Sanae-myeon, Hwacheon-gun	18 (2)	6
	Gwangsi-ryeong, Yanggu-eup, Yanggu-gun	-	7
	Saeteo, Ildong-myeon, Pocheon-gun	18 (2)	8
	Pung-san, Hwacheon-eup, Hwacheon-gun	18 (3)	9
	Seoweon, Sinbuk-eup, Chuncheon-si	18 (6)	10
	Cheoljung, Hwachon-myeon, Hongcheon-gun	18 (2)	11
	Ooga, Yangyang-eup, Yangyang-gun	18 (3)	12
	Yongpyeong, Wangsan-myeon, Gangneung-si	18 (11)	13
	Wondong, Buk-myeon, Yeongwol-gun	18 (4)	14
	Daehwa, Daehwa-myeon, Pyongchang-gun	18 (3)	15
	Ro-dong, Yongpyeong-myeon, Pyongchang-gun	18 (4)	16
	Jangseong-dong, Taebaek-si	18 (3)	18
	Sabuk, Sabuk-eup, Jeongseon-gun	18 (5)	19
	Ssarijae, Gohan-eup, Jeongseon-gun	18 (1)	21
Chungcheongbuk-do	Danyang, Danyang-eup, Danyang-gun	18 (3)	23
	Shindang, Hansu-myeon, Jecheon-si	-	24
	Hanam, Noeun-myeon, Chungju-si	18 (3)	25
	Galmok, Boeun-up, Boeun-gun	18 (5)	26
	Piban, Hoebuk-myeon, Boeun-gun	18 (2)	27
	Hagae, Tanbu-myeon, Boeun-gun	-	29
	Yeon-gok, Jincheon-eup, Jincheon-gun	18 (2)	30
Chungcheongnam-do	Taejo-an, Oesan-myeon, Buyeo-gun	18+1~2B (5)	58
	Magok-sa, Sagok-myeon, Gongju-gun	-	59
	Gaeshim-sa, Unsan-myeon, Seosan-gun	18+0~1B (5)	60
Gyeongsangbuk-do	Gasan-sanseong, Gasan-myeon, Chilgok-gun	18 (4)	2
	Hyeon-dong,Socheon-myeon, Bonghwa-gun	-	17
	Bu-Seok, Buseok-myeon, Yeongju-si	18 (4)	20
	Jungryeong, Punggi-eup, Yeongju-si	18 (5)	22
	Seowon, Naeseo-myeon, Sangju-si	-	28
	Seokgul-am, Yangbuk-myeon, Gyeongju-si	36 (4)	31
	Dosan, Dosan-myeon, Andong-si	-	38
	Sacheon, Byeonggok-myeon, Yeongdeok-gun	-	39
	Bongjeong-sa, Seohu-myeon, Andong-si	18 (2)	40
	Jiri, Budong-myeon, Cheongsong-gun	-	41
	Deog-gye, Hyeonseo-myeon, Cheongsong-gun	-	42
	Naeryong, Budong-myeon, Cheongsong-gun	18 (1)	43
	Ok-san, Dalsan-myeon, Yeongdeok-gun	18 (1)	44
	Seongnyu-gul, Geunnam-myeon, Uljin-gun	-	45
	Bogyeong-sa, Songna-myeon, Pohang-si	18 (2)	46
	Seongu, Onjeong-myeon, Uljin-gun	18 (3)	47
	Naechil, Sannae-myeon, Gyeongju-si	36 (3)	48
	Hwayang, Cheongdo-eup, Cheongdo-gun	36 (1)	49
Daegu-si	Palgong-san, Dohak-dong, Hak-dong	18 (9)	1
Gyeongsangnam-do	Haein-sa, Gaya-myeon, Geochang-gun	18 (7)	33
	Gaji-san, Sangbuk-myeon, Milyang-gun	36 (5)	35
	Naewon-sa, Habuk-myeon, Yangsan-gun	36 (4)	36
	Gosa, Jinjeon-myeon, Masan-si	18 (2)	50
	Pyeonggu, Ssangbaek-myeon, Hapcheon-gun	18 (5)	51
Jeollabuk-do	Jiri-san, Sannae, Namwon-gun	18 (2)	32
	Geumsan-sa, Geumgu-myeon, Gimje-gun	18+1B (1)	56
	Anshim-sa, Daedung-san, Beolgok-myeon, Wanju-gun	18 (4)	57
Jeollanam-do	Muncheok, Muncheok-myeon, Gwangyang-gun	18 (7)	34
	Ipam-san, Sinjeong-dong, Jeongeup-si	18 (6)	52
	Yuma, Mohu-san, Nam-myeon, Hwasun-gun	18 (3)	53
	Wolchul-san, Yeongam-eup, Yeongam-gun	18 (6)	54
	Borim-sa, Yuchi-myeon, Gangheung-gun	18+0~1B (5)	55
Busan-si	Geumjeong-sanseong, Geumjeong-gu	36 (5)	37
Cheju-do	Near the hotel, Pukcheju-gun	18(3)	61
	South part of Mt. Hallasan, Sogwipo-si	18(3)	62

[a] : Numbers in parentheses shows the number of plants examined. [b] : Population numbers are corresponding to Fig. 2.

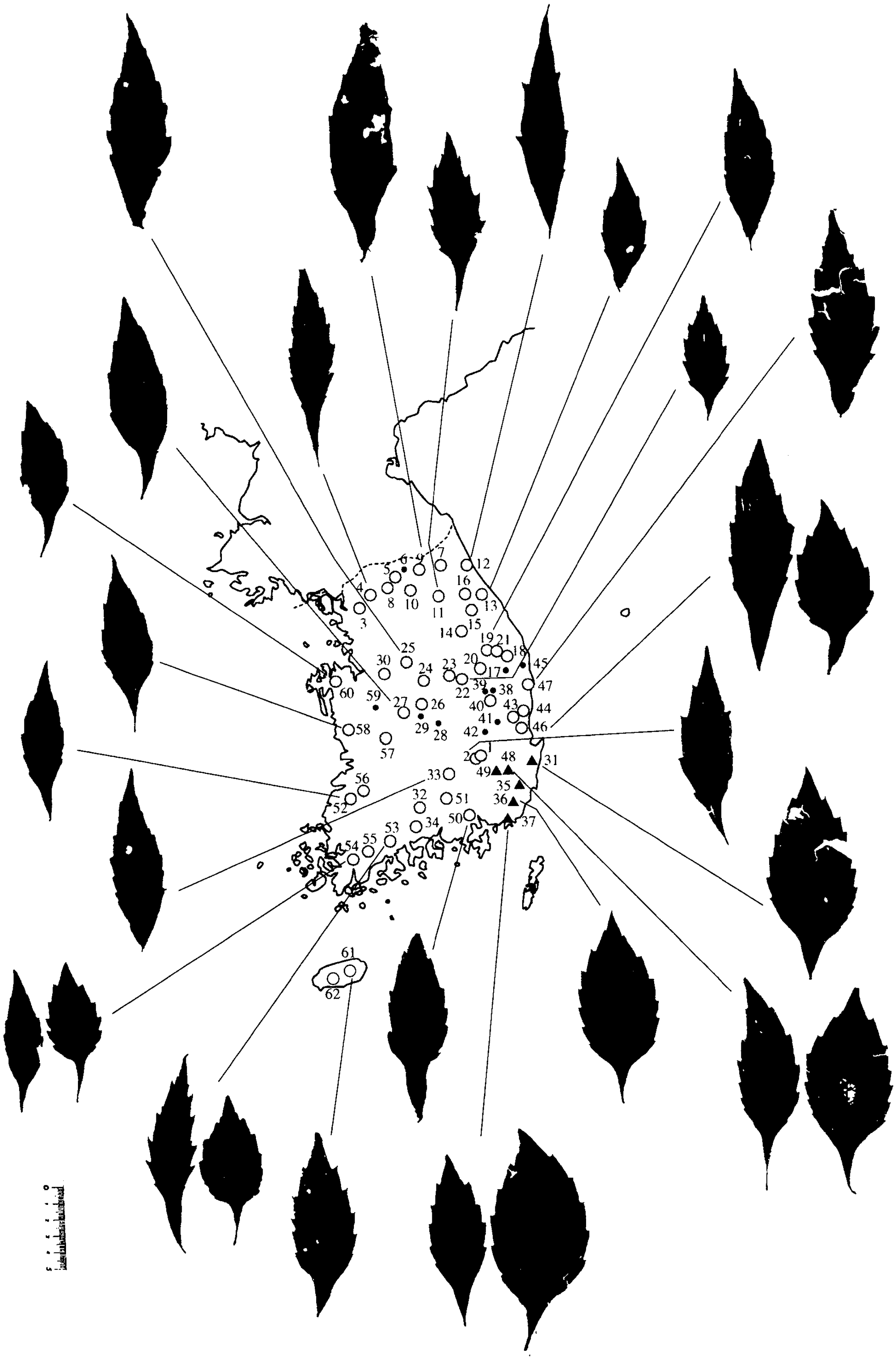

FIG. 1. Sampling localities and leaf shape variation. Large open circle = diploid, closed triangle = tetraploid, small closed circle = unknown. Scale bar = 5 cm.

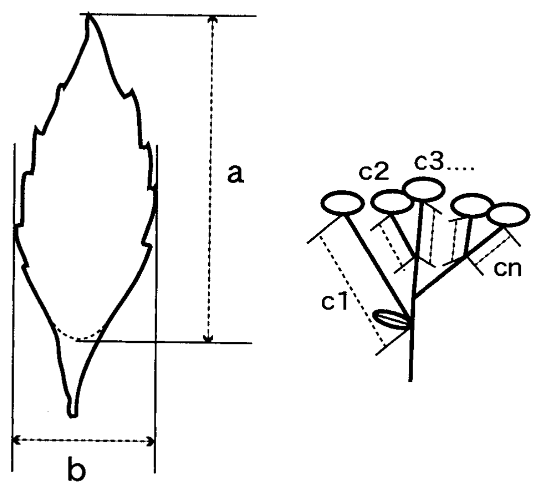

FIG. 2. Measurements of leaves and peduncles. a, leaf blade length. b, leaf blade width. c, peduncle length (the average of c1, c2,...., cn is used).

conducted simultaneously in liquid of 1% aceto-orcein (45% acetic acid) and 1N HCl (9:1) for about 24 hours before squash. The aerial parts of the plants gained in the field were prepared as voucher specimens for morphological analyses and are deposited in KYO.

For morphological analyses, the length and the width of a leaf and the length of peduncles were measured (Fig. 2). A leaf without serious damages was chosen from the largest leaves of a specimen. As the peduncle length, the average length of two to seven peduncles in a cluster was used. A cluster was determined as a group of heads arranged above the uppermost bracteole which had distinct midvein. For measurement, a cluster was chosen from the clusters closest to the main axis.

Results and Discussion

Chromosome features and distribution

Chromosome numbers were determined for the 189 plants from 51 populations. Among them, 167 plants from 45 populations were diploids, $2n = 18$, and 22 plants from 6 populations were tetraploids, $2n = 36$, based on $x = 9$. The longest two chromosomes of diploids and the longest four chromosomes of tetraploids had secondary constriction on their short arms. And the shortest chromosomes of both diploids and tetraploids were longer than the half-length of the longest ones. One or two additional B-chromosomes were observed in some plants of four populations (Table 1). B-chromosomes were smaller than any other A-chromosomes. These karyological features are coincident with the previous studies of the most members of *Aster ageratoides* complex in Japan (Huziwara 1957, Matsuda & Suyama 1980, Matsuda & Shinohara 1985, Irifune 1990, Soejima 1992, 1993), China (Soejima *et al.* 1999) and Taiwan (Soejima & Peng 1998).

Diploids and tetraploids were not sympatric in any populations examined. The distribution of diploid and tetraploid populations is shown in Fig. 1. It is obvious that diploid populations are distributed widely and very common in Korea. On the other hand, tetraploid populations are restricted to a small region of southeastern part.

Morphological features in relation to the ploidy level

The important characters to distinguish taxa within the *Aster ageratoides* complex are such as leaf shape, hair density on stems and leaves, head size, and color of ligules. In Korea, leaf shape varies rather widely from elliptic-lanceolate to ovate. But it seems that there are not marked variation in hair density, head size, and color of ligules. The stems and the lower surface of leaves are nearly glabrous or sparsely pubescent with short hairs, and the upper surface of the leaves is usually strigullose with sparse rigid short hairs. The diameter of the heads including the ligules is about 1.5-2 cm at anthesis. The ligules are usually white but sometimes tinged with pale purple on the outside especially before anthesis. Among other characters, the length of peduncles of the heads shows a relatively wide variation range.

The leaf shape varies continuously from elliptic-lanceolate to ovate in both diploids and tetra-

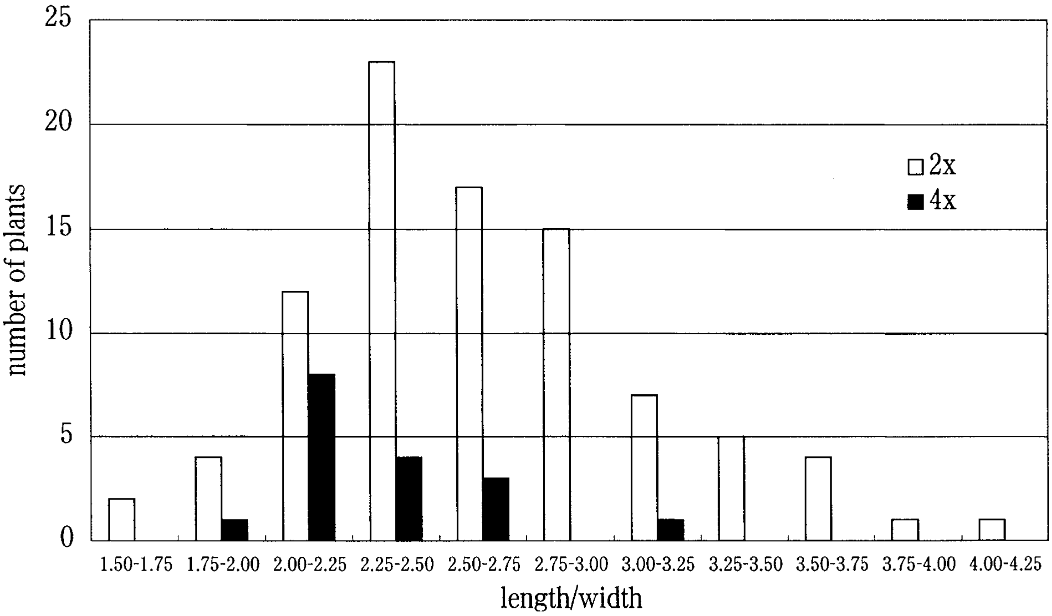

FIG. 3. Frequency distribution of leaf length/width length.

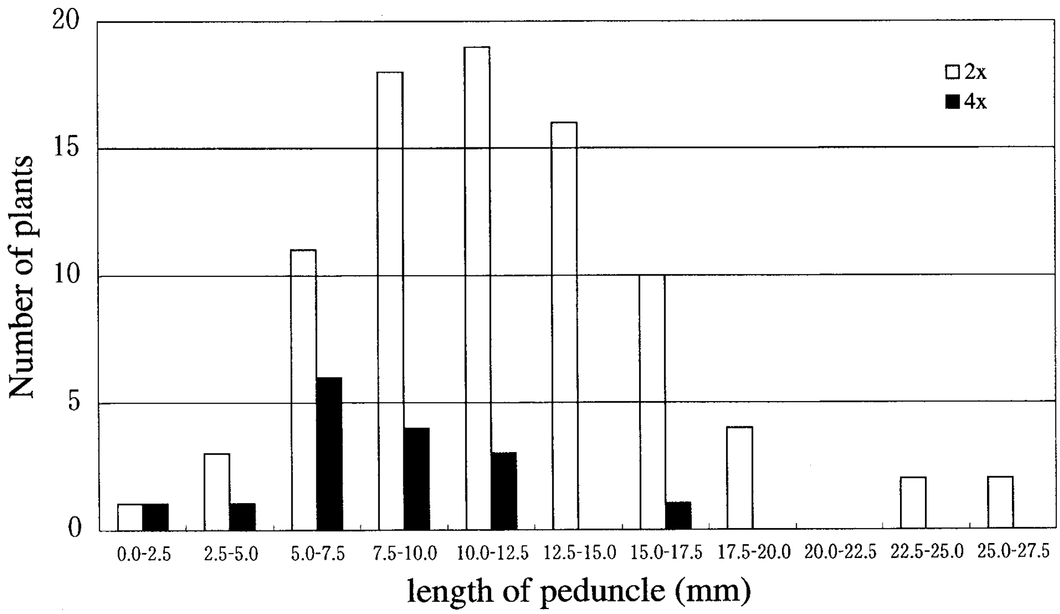

FIG. 4. Frequency distribution of length of peduncle

ploids. There is not statistically significant difference between diploids and tetraploids, but tetraploids tend to have ovate leaves in comparison with diploids (Fig. 3). Long peduncles make the inflorescence loose, while short ones make them dense. Although there is no significant difference between diploids and tetraploids, tetraploids tend to have shorter peduncles than diploids (Fig. 4). It seems that there is a weak correlation between leaf shape and peduncle length; plants with ovate leaves tend to have short peduncles (Fig. 5). However, the correlation between the leaf shape and the peduncle

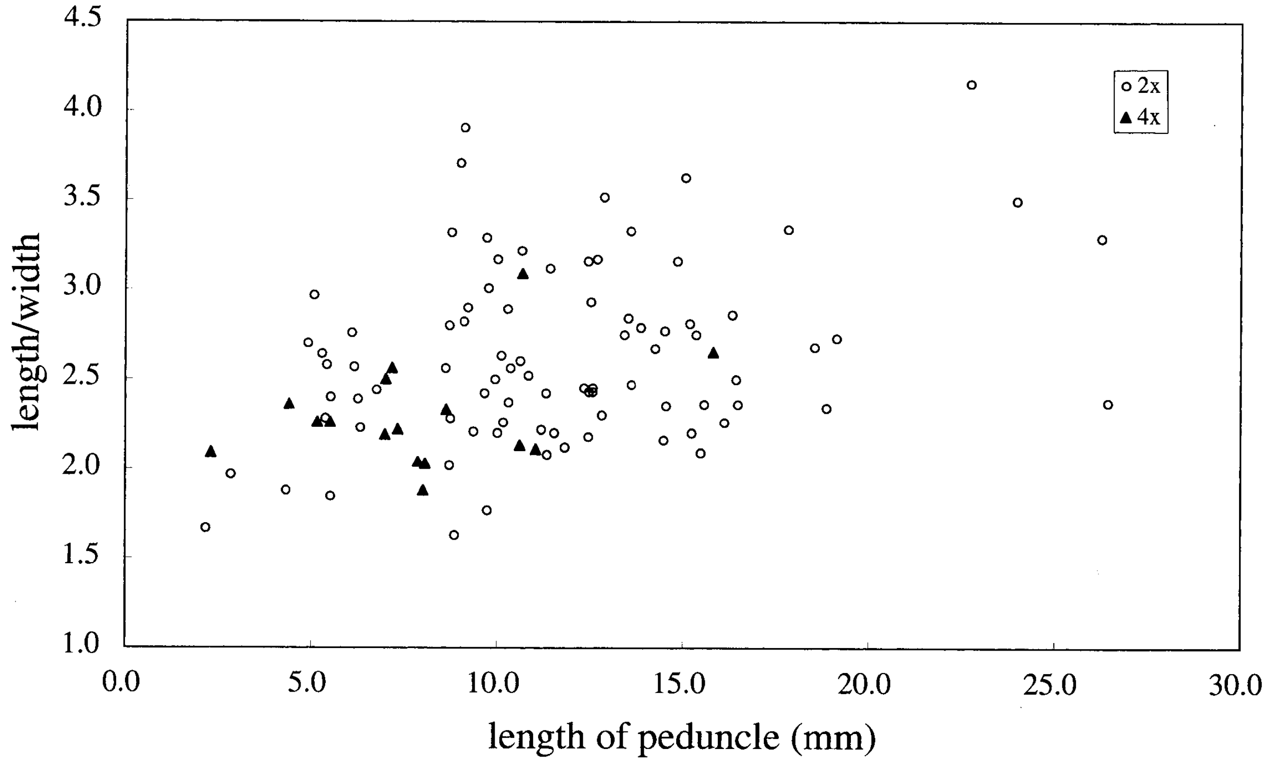

FIG. 5 Scatter diagram showing relationship between leaf length/leaf width and peduncle length.

length is not statistically significant. In a total, the ranges of morphological variation of tetraploids are included in those of diploids.

Geographic cline

Diploids are distributed widely and abundant throughout Korea, but their variation of the leaf shape shows a geographic cline as ovate leaves occur in the southern and southeastern part of Korea (Fig. 1). As is shown in Fig. 1, only lanceolate-leaved diploids appear in the northern part, but both lanceolate leaved and ovate leaved diploids are sympatric in some southern populations, such as Populations 46, 53, and 54 (Fig. 1). The leaf shape varies from elliptic-lanceolate or lanceolate leaves to ovate leaves continuously within a population. Tetraploids tend to have ovate leaves (Fig. 3), but they also have rather wide variation range in the leaf shape from elliptic-lanceolate to ovate even within a population (37, 48 in Fig. 1). The leaf shape variation is continuous and they cannot be clearly divided into two morphologically distinguishable groups.

Considering the parapatric occurrence of tetraploids with diploids (Fig. 1) and their ranges of morphological variation, which do not exceed those of diploids (Fig. 3-5), the origin of tetraploids could have been related to diploids in the southern part of Korea. The rather wide morphological variation shown among tetraploids could be attributed multiple polyploidization in situ, or some genetic exchange through backcross such as unreduced gametophyte of diploid and reduced gametophyte of tetraploid.

Taxonomic considerations

In Korea, only *Aster ageratoides* var. *ageratoides* has been reported in the *A. ageratoides* complex. Following Ito & Soejima (1995), the plants with lanceolate to elliptic lanceolate leaves are identified as var. *ageratoides*. But the plants with ovate leaves found in this research quite resemble to *A. ageratoides* var. *ovalifolius*, which is considered to be

endemic to Japan. The variety *ovalifolius* occurs on the Japan Sea side, mainly in the Hokuriku district including Yamagata and Niigata Prefectures as its center, however, it intermittently occurs westward along the Japan Sea side to Chugoku district and Tsushima Islands. The populations are separated by certain geographic distances in west part of its distribution area, which could suggest that the var. *ovalifolius* of Japan has different origin from that of the ovate leaved ones of southern Korea.

The morphological variation ranges of var. *ageratoides* and var. *ovalifolius* are continuous in Japan as is the same to the situation of both diploids and tetraploids in the southern part of Korea. That is the reason why var. *ovalifolius* is recognized at variety rank. This study revealed the cytogeographical distribution and the morphological variation in Korea, and showed the possibility of existence of diploid and tetraploid var. *ovalifolius* in Korean Peninsula. On the other hand, only tetraploids were known in var. *ovalifolius* of Japan to date (Soejima unpublished). To consider the relationship between var. *ovalifolius* in Japan and the ovate-leaved diploids and tetraploids in Korea, taxonomically revisional investigation of these varieties including other taxa of this complex and some genetic evidence such as molecular markers are needed.

It is noted that the diploid plants of the population 62, found in Cheju Island, are very small in the height. They have lanceolate leaves and quite similar to the var. *ageratoides*. The size of the heads is not so much smaller than others, but the plant height is between 10-30cm at anthesis. This population appeared along a small stream of the mountain, growing among mosses on the rocks, which might be under water when the water rises. Such environmental condition could cause the miniaturization of plants. Another population found in Cheju Island (population 61) is also diploid, but the height of the plants at anthesis is 80-100cm, which is similar to the other diploid and tetraploid populations in the Korean Peninsula. The plants of the population 61 have lanceolate leaves and are identified as var. *ageratoides*. Although the size difference is noticeable, here we consider the plants of both the two populations of Cheju Island as *Aster ageratoides* var. *ageratoides*.

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References

Huziwara, Y. 1957. Karyotype analysis in some genera of Compositae. III. The karyotype of the *Aster ageratoides* group. Amer. J. Bot. 44: 783-790.

Irifune, K. 1990. Karyomorphological study on speciation of the *Aster ageratoides* subsp. *amplexifolius* complex in Japan. J. Sci. Hiroshima Univ., Ser. B. Div. 2, 23: 163-238.

Ito, M. & A. Soejima. 1995. *Aster. In*: Iwatsuki, K., T. Yamazaki, D. E. Boufford & H. Ohba. (eds.), Flora of Japan 3b: 59-73. Kodansha, Tokyo.

Kitamura, S. 1993. History of Sino-Japanese region. *In*: Distribution and Differentiation of Plants. Kitamura Siro Sen-shu V., pp. 65-145. Hoikusha, Osaka. (in Japanese)

Ling, Y. & Y.-L. Chen. 1985. *Aster. In*: Ling, Y., Y.-L. Chen & C. Shih. (eds.) Fl. Repub. Popul. Sinicae. 74: 133-254. (in Chinese)

Matsuda, T. & K. Suyama. 1980. Polyploids and distribution of *Aster ageratoides* subsp. *leiophyllus* group in the Kanto district and surrounding area. I. Sci. Rept. Yokohama Natl. Univ., Sec. 2, 27: 7-18.

—— & N. Shinohara. 1985. Polyploids and distribution of *Aster ageratoides* subsp. *leiophyllus* group in the Kanto district and surrounding area. II. Sci. Repts. Yokohama Natl. Univ., Sec. 2, 32: 11-26.

Soejima, A. 1992. Taxonomical study of *Aster leiophyllus* complex (Compositae) in Kanto district, Japan, with special reference to ploidy level. Bot. Mag. Tokyo 105: 13-28.

——. 1993. A study of the morphological and cytological features of *Aster leiophyllus* complex (Compositae)

in Kyushu, Japan. Acta Phytotax. Geobot. 44: 35-51.
—— & C.-I. Peng. 1998a. Cytological features of the *Aster ageratoides* complex (Asteraceae) in Taiwan. Bot. Bull. Acad. Sin. 39: 299-302.
—— & ——. 1998b. *Aster*. *In*: Flora of Taiwan, Second Edition, 4: 848-868. Editorial Committee of the Flora of Taiwan, Second Edition, Taipei.
——, S.-G. Wu, & K. Iwatsuki. 1999. The *Aster ageratoides* complex (Asteraceae) in northeastern Yunnan, China: cytological and morphological features. Acta Phytotax. Geobot. 50: 179-185.

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